SCIENTIFIC CRITERIA DOCUMENT FOR THE DEVELOPMENT OF A PROVINCIAL WATER QUALITY GUIDELINE FOR ETHYLBENZENE

NOVEMBER 1994

Ontario

Ministry of
Environment
and Energy

ISBN 0-7778-3013-2

SCIENTIFIC CRITERIA DOCUMENT

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NOVEMBER 1944
REPRINTED JANUARY 1995

Cette publication technique
n'est disponible qu'en anglais.

PIBS 3231E

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November 1994

ACKNOWLEDGEMENTS

We gratefully acknowledge Dr. D.M. Trotter of Monenco Consultants Ltd, John Ralston, Wolfgang Scheider, Tom Dickie, Tim Fletcher, Dave Rokosh, E. Hagmajer, Sum Chi Li, and other members of the MOEE Aquatic Criteria Development Committee for contributing to the development of this guideline document.

In addition, review comments were received from several sources including regional and district offices, the Air Resources Branch, the Waste Management Branch, the MISA Advisory Committee, and the Advisory Committee on Environmental Standards of the Ministry of the Environment and Energy, Dr. G. Dixon (University of Waterloo), Dr. J. Meyer (University of Wyoming), and Dr. J. Giesy (Michigan State University).

The public were notified of the proposed Provincial Water Quality Guideline for ethylbenzene through the Environmental Bill of Rights Electronic Registry and given the opportunity to comment in accordance with the Environmental Bill of Rights.

PREFACE

The Ontario Ministry of Environment and Energy (MOEE) develops Provincial Water Quality Objectives or Guidelines for those substances deemed to be of environmental concern in Ontario as determined through a screening process which considered persistence, potential to bioaccumulate, acute and chronic toxicity, and potential presence in the aquatic environment. In addition, Ministry staff with a direct responsibility for managing possible effects of contaminants may request an evaluation.

Provincial Water Quality Objectives and Guidelines (PWQO/Gs) are numeric or narrative criteria intended to protect all life stages of aquatic organisms for indefinite exposures and/or they are intended to protect recreational uses of water. Objectives or guidelines do not take into account analytical detection or quantification limits, treatability or removal potential, socio-economic factors, natural background concentrations, or potential transport of contaminants among air, water and soil. They represent a desirable water quality for the protection of designated uses of surface waters in Ontario.

The process for deriving these criteria is detailed in Ontario's Water Quality Objective Development Process (1992) and is available from the ministry's Public Information Centre, 135 St. Clair Avenue, Toronto, Ontario M4V 1P5 (Tel. (416) 323-4321 or 1-800-565-4923). The toxicology literature is reviewed for all of the following areas: aquatic toxicity, bioaccumulation, mutagenicity and aesthetic considerations. The final criterion is based on the lowest effect reported for any of these. Where numeric criteria are set to protect aquatic life, the number is derived by dividing the lowest adverse effect concentration by a safety factor for Objectives or an "uncertainty factor" for Guidelines. The size of the uncertainty factor reflects the quality and quantity of data available and the potential of the material to bioaccumulate.

Policies and procedures which govern the uses of PWQO/Gs are contained in the booklet - Water Management (1984) - which deals with all aspects of Ontario's water management policy. These policies and procedures make provision for considering such factors as natural background levels, socio-economic factors, treatability, and the waste assimilative capacity of the receiving environment in applying the PWQO/Gs in site-specific situations. PWQO/Gs are used to: i) classify receiving waters for water management purposes; ii) assess contaminant discharges to the aquatic environment; and iii) derive water quality-based effluent limits which may be included in Certificates of Approval which are issued to regulate effluent discharges. Where better water quality is required to protect other beneficial uses of the environment in a given location, appropriate criteria and factors, including public health considerations, are taken into account.

EXECUTIVE SUMMARY

A Provincial Water Quality Guideline (PWQG) was developed for ethylbenzene for the protection of aquatic life. The physical-chemical properties, aquatic toxicity, bioaccumulation potential, taste and odour characteristics, and genotoxicity potential of ethylbenzene were considered in the development of the PWQG.

Ethylbenzene is a colourless liquid that smells like gasoline. It occurs naturally in coal tar and petroleum and is found in many consumer products such as paints, inks, insecticides and gasoline. It is used primarily for producing styrene and as a solvent in the chemical, paint, and rubber industries. The major producers of ethylbenzene in Ontario are located near Sarnia.

Ethylbenzene can enter the environment from releases associated with its production, use, storage, and transportation, including chemical spills. Some important dischargers of ethylbenzene into Ontario surface waters are the chemical manufacturing and petroleum refining sectors. The total loading of ethylbenzene to the aquatic environment by the organic chemical manufacturing sector is approximately 3 kg/day.

Natural processes can remove ethylbenzene from land, air, and water and reduce environmental exposures. As a result, ambient levels remain low and there is little tendency for ethylbenzene levels to build up in the environment over time. In Ontario, surface water concentrations are usually less than 0.0001 mg/L or they are not detectable and atmospheric concentrations are generally less than 10 $\mu g/m^3$. The lowest MOEE detection limit for routine analysis of ethylbenzene in water is 0.00005 mg/L.

Ethylbenzene is highly toxic to aquatic organisms when water concentrations exceed approximately 2 mg/L during short-term exposures. Reported levels of toxicity include a 96h-LC50 of 4.2 mg/L for rainbow trout, a 24h-EC50 of 2.2 mg/L for water flea (Daphnia magna), and a 72h-EC50 of 4.6 mg/L for Selenastrum carpicornutum (Galassi et al. 1988).

The Provincial Water Quality Guideline of 0.008 mg/L was derived by dividing the lowest adverse effect concentration (2.2 mg/L) by a final uncertainty factor of 290. Since the water quality criterion for the protection of aquatic life is more stringent than the taste and tainting protection values derived for ethylbenzene, it is recommended as the PWQG.

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1.0 INTRODUCTION

Ethylbenzene (C_8H_{10}) is a colourless liquid that smells like gasoline. It occurs naturally in coal tar and petroleum and is found in many products such as paints, inks, insecticides and gasoline (ATSDR 1990).

In Canada, ethylbenzene is used primarily for producing styrene and as a solvent in the chemical, paint, and rubber industries (Environment Canada 1984). In Ontario, the major producers of ethylbenzene are located in Sarnia (Polysar and Dow Chemical Canada) (Corpus Information Services 1987). In 1986, Ontario nameplate production capacity was 764 kilotonnes per year.

The effects of ethylbenzene on human health have been recently reviewed (RTECS 1993; IRIS 1992; ATSDR 1990; Health and Welfare Canada 1988). Limited health effects information is available regarding dermal exposures to aqueous solutions of ethylbenzene. The U.S. Environmental Protection Agency has given ethylbenzene a cancer rating of "D" (not classifiable as to human carcinogenicity because of a lack of animal and human studies). The U.S. EPA has also developed an oral reference dose of 0.1 mg/kg/day (equivalent to 7 mg/day for a 70 kg person). The reference dose is an estimate of the daily exposure of the human population to a potential hazard that is likely to be without risk of deleterious effects during a lifetime.

The purpose of this document is to develop a Provincial Water Quality Guideline for ethylbenzene for the protection of aquatic life. Ethylbenzene was identified as priority for guideline development because it was deemed to be a substance of environmental concern in Ontario and was present in industrial point source discharges to Ontario surface waters. In addition, a guideline for the protection of aquatic life was developed because ethylbenzene is a common pollutant released into water through chemical spills.

1.1 SOURCES OF ETHYLBENZENE IN THE ENVIRONMENT

Ethylbenzene may enter the environment from discharges or spills (including petroleum spills) associated with its use, production, storage and transportation (Fishbein 1985). Atmospheric emissions are expected from industries by way of process and fugitive emissions and evaporation from wastewater streams. Also, it is anticipated that process residues and sludges containing these chemicals may enter landfills.

Ethylbenzene has been detected in the effluents of various industries monitored in Ontario under the MISA (Municipal Industrial Strategy for Abatement) Program. These industries were associated with the Organic Chemical Manufacturing (OCM) and Petroleum Refining sectors.

In the OCM sector, ethylbenzene was detected in effluents indicating inputs to the St. Clair River near Sarnia and the St. Lawrence River near Kingston, Maitland and Morrisburg. Average concentrations ranged from 0.0002 to 0.008 mg/L (MOEE unpublished data, 1989-1991). The total sector loading of ethylbenzene is approximately 3 kg/day.

In the Petroleum sector, ethylbenzene was detected in 3 percent of the samples for all 7 refineries located in Ontario. The maximum level found was 0.003 mg/L (average was 0.00002 mg/L) indicating inputs to the St. Clair River near Sarnia, Lake Erie near Nanticoke, and Lake Ontario near Oakville (MOE 1990).

In a study of 37 municipal water pollution control plants (WPCPs), ethylbenzene was detected in effluents from 5 plants (Environment Ontario 1988). The average concentration was 0.001 mg/L and the maximum level found was 0.017 mg/L. In addition, ethylbenzene was detected in treated sludge from 11 plants at an average concentration of 0.6 mg/kg and the highest level found was 500 mg/kg. These 37 WPCPs accounted for approximately 74 percent of the total Ontario flow of municipal wastewaters in 1987.

1.2 ENVIRONMENTAL FATE AND PROPERTIES

When released into water, ethylbenzene will evaporate fairly rapidly into the atmosphere, with a half-life ranging from hours to a few weeks (Howard 1989). Also, the high Henry's Law Constant (Table 1) indicates it will volatilize rapidly. The half-life for volatilization of ethylbenzene from a column of water one metre deep at 20°C was estimated to be 3.1 hours (Thomas 1982).

Biodegradation of ethylbenzene in water is expected to be rapid (half-life of about 2 days) after degrading microorganisms become established (reviewed by Howard 1989). Microflora isolated from groundwater contaminated with gasoline were found to completely degrade ethylbenzene from a gasoline mixture within 8 days at 13°C (Jamison et al. 1976).

Ethylbenzene is only slightly soluble in water (Table 1). It is resistant to hydrolysis (Howard 1989). Furthermore, direct photolysis of ethylbenzene in surface water is not expected to be an important removal process (Howard 1989).

Based on a log octanol/water partition coefficient (Kow) of approximately 3.2 (Table 1), ethylbenzene may be adsorbed by sediment, but significant bioconcentration in fish is not expected to occur (Howard 1989; Hawker and Connell 1988; Mabey et al. 1982). Also, based on a bioconcentration factor (BCF) at equilibrium of 15.5 for goldfish (Carassius auratus) (Ogata et al. 1984), ethylbenzene does not appear to bioconcentrate in aquatic organisms.

When released onto soil, ethylbenzene will evaporate into the atmosphere and may leach into groundwater, especially in soil with low organic carbon content (Howard 1989). However, ethylbenzene may be relatively persistent in groundwater where volatilization is not a viable process. Also, biodegradation will occur although the extent will depend on the microbes present, the concentration of ethylbenzene, the presence of other compounds, and the amount of oxygen present.

Once in the atmosphere, ethylbenzene will be transported until it removed by physical (i.e., partitioning into clouds or rainwater) or chemical processes (ATSDR 1990). Ethylbenzene will be removed mainly by chemical transformations caused by the suns energy (photooxidation) with a half-life of 0.5 to 2 days (Howard 1989). Moreover, ethylbenzene may be transformed into photochemical aerosols or haze associated with smog or PAN (peroxyacetylnitrate) which is a toxic component of smog (ATSDR 1990).

Human populations are primarily exposed to ethylbenzene from ambient air, particularly in highly populated areas, areas of heavy automotive traffic, and around gasoline stations (ATSDR 1990; Howard 1989). Higher exposures may also exist near production and manufacturing facilities. In addition, indoor air may have higher concentrations than outdoor air because ethylbenzene may build up after use of household cleaning products, varnishes, paints or tobacco products.

In a U.S. study, tobacco smoke was found to be a main source of human exposure to ethylbenzene (ATSDR 1990). Although information is limited on dietary exposures, ethylbenzene does not significantly accumulate in the food chains (in comparison to bioaccumulative substances such as PCBs and DDT); therefore, exposure through this route is unlikely to be of concern (ATSDR 1990).

Ethylbenzene has been detected throughout North America in effluents from municipalities and industries, industrialized river basins, groundwater, sediments, soil, and air (ATSDR 1990; Howard 1989; Fishbein 1985). Despite its widespread presence, physical, chemical and biological processes can remove ethylbenzene in all media and reduce environmental exposures. Hence, ambient levels remain low because of photooxidation in air, low water solubility, and high volatility from water and soil.

In 1986, a survey was undertaken to investigate the potential impact of point source discharges to the St. Clair River (Environment Ontario 1991). Water samples were collected from 43 stations located throughout the river in May, July, and October. Ethylbenzene was

not detected in 284 samples collected at the detection limit of 0.001 mg/L. However, detectable levels of ethylbenzene were found in caged mussels (Elliptio complanata) deployed near Sarnia. Average concentrations ranged from 0.01 to 0.13 µg/g after 4 weeks of exposure.

As part of the Ontario Drinking Water Surveillance Program which includes raw water samples collected from surface and ground waters from urbanized or industrialized areas located throughout the Great Lakes basin, average concentrations of ethylbenzene were usually below 0.0001 mg/L (MOEE unpublished data, 1992). The maximum levels found were 0.00055 and 0.00025 mg/L near Kingston and Sarnia, respectively. The MOEE routine analytical detection limit for ethylbenzene in water is 0.00005 mg/L ("clean" water analysis). The Canadian Drinking Water Guideline for public water supplies is 0.0024 mg/L (aesthetic objective).

In the United States, ethylbenzene was detected in soil samples collected at 25 percent of 2,783 hazardous waste sites studied by the Environmental Protection Agency (ATSDR 1990). The geometric mean concentration in detectable samples was 0.07 mg/kg.

In a survey of 7 landfill sites tested in Ontario, ethylbenzene was detected in leachate from 6 sites. The levels reached 0.219 mg/L and averaged 0.012 to 0.150 mg/L (MOEE unpublished data, 1988).

As part of the MOEE Volatile Organic Compounds Monitoring Network, ambient air concentrations of ethylbenzene for six cities (Thunder Bay, Sault Ste. Marie, Windsor, Toronto, and Hamilton) ranged from not-detectable (less than 0.1 $\mu g/m^3$) to 9 $\mu g/m^3$ (Environment Ontario 1992). The Ontario Air Quality criterion or acceptable level is 4000 $\mu g/m^3$.

In summary, natural processes can remove ethylbenzene from land, air, and water and reduce environmental exposures. As a result, ambient levels remain low and there is little tendency for ethylbenzene levels to build up in the environment over time.

2.0 AQUATIC TOXICITY

Criteria used for classifying available toxicity data as either primary or secondary information are described in "Ontario's Water Quality Objective Development Process" (Environment Ontario 1992). In general, primary toxicity studies involve acceptable test procedures, conditions, and controls, measured toxicant concentrations, and flow through or renewal exposure conditions. Secondary toxicity studies usually involve unmeasured toxicant concentrations, static bioassay conditions, and unsatisfactory reporting of experimental data. Generally, acute toxicity studies involve test durations of 96 hours or less for vertebrates or 48 hours or less for invertebrates. Chronic toxicity data studies include complete life cycle tests and partial life cycle tests involving early life stages.

2.1 ACUTE TOXICITY

2.1.1 Vertebrates

Galassi et al. (1988) reported 96h-LC50 values (median lethal concentrations) of 4.2 and 9.6 mg/L for rainbow trout (Oncorhynchus mykiss) and guppy (Poecilia reticulata), respectively (Table 2). These results were considered as primary acute data as defined by Environment Ontario (1992).

All other available toxicity data were considered as secondary information (Table 2). The 96h-LC50 (or TLm) values reported for fathead minnows (Pimephales promelas) ranged between 9.1 and 48.5 mg/L (Geiger et al. 1990; Pickering and Henderson 1966). Johnson and Finlay (1980) reported a 96h-LC50 of 14 mg/L for rainbow trout. Other 96h-LC50 values reported for goldfish (Carassius auratus), bluegill sunfish (Lepomis macrochirus), channel

catfish (Ictalurus punctatus) and guppy (Lebistes reticulatus) ranged between 29 and 210 mg/L (Buccafusco et al. 1981; Johnson and Finley 1980; Pickering and Henderson 1966).

2.1.2 Invertebrates

Primary toxicity information for aquatic invertebrates was limited to a 24h-EC50 (immobilization) value of 2.2 mg/L reported for the water flea (Daphnia magna) tested in closed bottles (Galassi et al. 1988).

Similarly, Bobra et al. (1983) reported a 48h-EC50 of 2.1 mg/L for Daphnia magna tested in sealed chambers. However, Leblanc (1980) reported a 48h-LC50 of 75 mg/L and a no observed adverse effect concentration of 6.8 mg/L for Daphnia magna tested in an open system. These two studies were both considered as secondary data since they were conducted using static test conditions and unmeasured toxicant concentrations.

2.2 CHRONIC TOXICITY

2.2.1 Vertebrates

Chronic toxicity studies for aquatic vertebrates exposed to ethylbenzene were not available.

2.2.2 Invertebrates

Chronic toxicity studies for invertebrates were not available.

2.2.3 Other Organisms (Plants, Protozoa, Rotatoria, and Bacteria)

Galassi et al. (1988) reported a 72h-EC50 of 4.6 mg/L, based on growth inhibition, for green algae (Selenastrum capricornutum) (Table 2). Similarly, Herman et al. (1990) reported an 8d-

EC50 of 4.8 mg/L for growth inhibition of S. capricornutum. Erben (1978) found a 6d-EC50 of approximately 173 mg/L for rotifers (Dicranophorus forcipatus) based on growth inhibition.

2.3 SUMMARY OF TOXICITY DATA

The ranges of toxicity exhibited by aquatic organisms exposed to ethylbenzene are summarized in Figure 1. Galassi et al. (1988) reported the lowest primary adverse effect concentrations for freshwater biota. These included a 96h-LC50 of 4.2 mg/L for rainbow trout and a 24h-EC50 of 2.2 mg/L for water flea (Daphnia magna). The 72h-EC50 of 4.6 mg/L for Selenastrum carpicornutum was the lowest reported effect concentration for algae and is considered secondary information (Galassi et al. 1988).

3.0 BIOACCUMULATION

Ogata et al. (1984) exposed goldfish (Carassius auratus) to a 1 mg/L solution of ethylbenzene and found a bioconcentration factor at equilibrium of 15.5. Therefore, based on a BCF and log Kow of 3.2 (Table 1), ethylbenzene is not expected to undergo significant bioaccumulation in aquatic animals.

4.0 MUTAGENICITY

The genotoxic effects of ethylbenzene have been recently reviewed (IRIS 1992; ATSDR 1990). In summary, genotoxicity studies have provided negative results in a variety of assays using bacteria (Salmonella and Escherichia coli strains) in the presence and absence of metabolic activation, yeast (Saccharomyces cerevisiae strains), Drosophila melanogaster (fruit fly), and in an in vivo assay using mouse bone marrow cells. Ethylbenzene also failed to induce sister-chromatid exchanges (SCEs) and chromosomal aberrations in chinese hamster ovary cells.

Although this study is not considered a positive result, Norppa and Vanio (1983) found a marginal SCE response was induced by a toxic dose of ethylbenzene in cultured human lymphocytes. Ethylbenzene was, however, found to be mutagenic in cultured mouse lymphoma cells (MacGregor et al. 1988).

A review of the scientific literature indicated there was no mutagenicity or genotoxicity information available for aquatic plants and animals exposed to ethylbenzene. As a result, there is insufficient information available to develop a numerical criterion for the protection of aquatic life.

5.0 ODOUR AND TASTE

For ethylbenzene in water, threshold odour concentrations (T.O.C.) of 0.1 mg/L at 15 °C and 0.14 mg/L were determined by Zoeteman et al. (1971) and Rosen et al. (1963), respectively. The lowest concentration of ethylbenzene in water that tainted or impaired the taste of yellow perch (Perca fluvatilus) was found to range between 0.25 and 0.5 mg/L (as reviewed by Persson 1984).

Alexander et al. (1982) measured aqueous taste and odour thresholds for ethylbenzene in odour-free water. The average taste threshold was 0.072 mg/L at 40 °C. The average odour threshold was 0.0024 mg/L at 60 °C. However, this odour threshold value is not considered representative of ambient conditions because aquatic temperatures are usually much lower. Also, this study showed that odour threshold values for several volatile substances were consistently higher at lower temperatures (i.e., 20 °C).

6.0 DERIVATION OF WATER QUALITY GUIDELINE

Since the toxicological database for ethylbenzene was limited, a Provincial Water Quality Objective could not be developed. Therefore, following standard procedures as outlined in Environment Ontario (1992), the process reverted to the derivation of a Provincial Water Quality Guideline for the protection of aquatic life.

Where numerical guidelines are set to protect aquatic life, the number is derived by dividing the lowest adverse effect concentration by an "uncertainty factor". The size of the uncertainty factor reflects the quality and quantity of data available and the potential of the material to bioaccumulate.

The Federal-Provincial Working Group on recreational water quality has not recommended limits for chemicals in recreational water for human exposure because of the lack of sufficient scientific information (Health and Welfare Canada 1992). Therefore, a recreational use water quality guideline for the protection of human health is not recommended at this time.

Humans dermally exposed to ethylbenzene exhibited rapid absorption through the skin (ATSDR 1990). The average amount of ethylbenzene absorbed after male subjects immersed one hand for up to 2 hours in aqueous solutions of 112 or 156 mg/L was 39 and 71 mg of ethylbenzene, respectively.

Using a pharmacokinetic skin absorption model, Shatkin and Brown (1991) estimated that human adults or children exposed to 0.1 mg/L of ethylbenzene while bathing for 20 minutes could result in a dose of approximately 0.5 mg. Since ethylbenzene in Ontario surface waters is present at much lower concentrations (i.e., less than 0.001 mg/L) or is not-detectable, this suggests that exposure through skin contact with water is likely insignificant.

6.1 CALCULATION OF THE FINAL UNCERTAINTY FACTOR

The choice of a baseline uncertainty factor depends on the octanol-water partition coefficient (Kow) of the substance (which is a useful indicator of bioaccumulation potential). Chiou and Schmedding (1982) reported a log Kow of 3.2. The measured BCF of 15.5 for goldfish exposed to ethylbenzene was also taken into consideration (Ogata et al. 1984). Therefore, a baseline uncertainty factor of 1000 was selected, since the BCF was less than 1000 and the log Kow was less than 4 (Environment Ontario 1992).

The final uncertainty factor was calculated based on the following toxicity information (Table 3):

A. The following data were used in the acute toxicity category:

1. The 96h-LC50 of 9.1 mg/L for fathead minnows (Pimephales promelas) was considered as secondary information. Although the test involved flow through conditions with measured toxicant concentrations, the toxicant concentrations fluctuated by more than 10% during the test (Geiger et al. 1990).

2. The 96h-LC50 of 9.6 mg/L for guppy (Galassi et al. 1988) was considered as primary information. This test involved renewal exposure conditions in sealed containers and measured toxicant concentrations.

3. The 96h-LC50 of 4.2 mg/L for rainbow trout (Oncorhynchus mykiss) was considered as primary information (Galassi et al. 1988). This test involved renewal exposure conditions in sealed containers and measured toxicant concentrations.

4. The 24h-EC50 of 2.2 mg/L for Daphnia magna was considered as primary information (Galassi et al. 1988). This test involved static exposure conditions in sealed containers and measured toxicant concentrations.

B. The following data were used in the chronic toxicity category:

1. The 6d-EC50 of approximately 173 mg/L for rotifers (Dicranophorus forcipatus) exposed in static unmeasured conditions was considered as secondary chronic information (Erben 1978). This information was used in the category for invertebrates as defined by Environment Ontario (1992).

2. The 72h-EC50 of 4.6 mg/L for algae (Selenastrum capricornutum) was considered as secondary information (Galassi et al. 1988).

Based on the above data and applying the appropriate calibration factors, a value of 290 was derived as the final uncertainty factor (Table 3).

6.2 CALCULATION OF THE GUIDELINE VALUE

The following guideline was set as a single value independent of other water quality parameters such as temperature. Since ethylbenzene is highly volatile, only primary toxicity studies were considered in selecting the lowest toxic effect concentration.

The 24h-EC50 of 2.2 mg/L for the water flea (Daphnia magna) was considered the lowest toxic effect concentration or critical value (Galassi et al. 1988). This value was divided by the final uncertainty factor of 290 to produce a preliminary guideline value of 0.008 mg/L (Table 3 and Figure 1).

Additional information that was considered in the development of a PWQG included:

1. The lowest reported aesthetic effect concentration considered acceptable for guideline development was a taste threshold value of 0.072 mg/L for ethylbenzene in water (Alexander et al. 1982). This value multiplied by a safety factor of 0.5 produced an taste protection value of 0.036 mg/L (Figure 1). Since the preliminary guideline value

based on toxicity is lower than the taste protection value, it should be protective against potential aesthetic effects of ethylbenzene.

2. Fish flesh tainting was found to occur at water concentrations between 0.25 and 0.5 mg/L (Persson 1984). Taking the lowest tainting value of 0.25 mg/L and multiplying it by a safety factor of 0.5 produced a tainting protection value of 0.13 mg/L (Figure 1). Since the preliminary guideline value is lower than this value, it is expected to protect against the tainting potential of ethylbenzene.

3. Most of the available data suggest ethylbenzene is not genotoxic, although one study reported mutagenic effects (Section 4.0). Furthermore, no information was available to develop a numerical mutagenicity criterion for the protection of aquatic life, since no acceptable genotoxicity information for fish, invertebrates, or plants was found. While the majority of evidence supports the classification of ethylbenzene as non-genotoxic, the possibility of its genotoxic hazard in aquatic organisms cannot be excluded.

The preliminary Guideline value of 0.008 mg/L, derived by dividing the lowest valid toxicological endpoint (24h-EC50 of 2.2 mg/L for Daphnia magna) by the final uncertainty factor of 290, is recommended as the Provincial Water Quality Guideline for ethylbenzene. The MOEE routine analytical detection limit for ethylbenzene in water is 0.00005 mg/L ("clean" water analysis).

7.0 RESEARCH NEEDS

To fulfil the minimum data requirements for developing a Provincial Water Quality Objective, additional acute and chronic toxicity studies involving warm and cold-water fish species and freshwater macroinvertebrates are needed.

8.0 AMBIENT WATER QUALITY CRITERIA OF OTHER AGENCIES

The Canadian Council of Resource and Environment Ministers developed a tentative ambient water quality guideline for ethylbenzene of 0.7 mg/L for the protection of aquatic life (CCREM 1987).

The Michigan Department of Natural Resources developed a criterion of 0.03 mg/L for the protection of aquatic life (MDNR 1987).

The U.S. EPA has not developed a water quality criterion for the protection of freshwater biota, although they report 32 mg/L is the lowest effect concentration (LEC) for acute toxicity (IRIS 1992).

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TABLE 1: PHYSICAL-CHEMICAL PROPERTIES

CHEMICAL:	CHEMICAL FORMULA:	CAS No:
Ethylbenzene	C_8H_{10}	100-41-4

PROPERTIES

MOLECULAR WEIGHT (MW):	106.17 g/mol	Verschueren (1983)
MELTING POINT:	- 94.97°C	Verschueren (1983)
BOILING POINT:	136.2°C	Verschueren (1983)
PHYSICAL STATE AT STANDARD TEMPERATURE AND PRESSURE:	liquid	Verschueren (1983)
DENSITY (D):	0.867 g/cm^3 at 20°C	Verschueren (1983)
MOLAR VOLUME (MW/D):	122.46 cm^3/mol (calc.)	
VAPOUR PRESSURE (Ps):	7 mm Hg (933 Pa) at 20°C	Verschueren (1983)
WATER SOLUBILITY (Cs):	152 mg/L at 20°C	Verschueren (1983)
HENRY'S LAW CONST.(Ps/Cs):	0.0084 atm - m^3/mol	Howard (1989)

PERSISTENCE

SURFACE WATER HALF LIFE:	hours to weeks	Howard (1989)
AQUATIC FATE:	volatilization	Callahan *et al.* (1979)

OCTANOL-WATER PARTITION COEFFICIENT (Kow)

RANGE OF AVAILABLE Log Kow VALUES:	3.2	Chiou & Schmedding (1982)
FINAL CHOSEN Log Kow VALUE:	3.2	

BASELINE UNCERTAINTY FACTOR FOR GUIDELINE DEVELOPMENT

IF Log Kow < 4.00, USE 1000 IF Log Kow ≥ 4.00, USE 10000

BASELINE UNCERTAINTY FACTOR: 1000

TABLE 2: AQUATIC TOXICITY DATA FOR ETHYLBENZENE

SPECIES	LIFE STAGE	RESPONSE KEY (1)	TEST CONDITIONS					EFFECT CONC. (mg/L)	DATA CODES KEY (2)	DATA QUALITY KEY (3)	REFERENCES
			pH	TEMP. (°C)	D.O. (mg/L)	ALK. (mg/L)	HARD (mg/L)				
VERTEBRATES											
Fathead minnow *(Pimephales promelas)*	34 days old (ave. 0.21g)	96h-LC50	7.39±0.12	26.1±0.12	7.0±0.26	43.0±0.52	45.6	12.1	F/M	SA	Geiger et al., 1986
	3.8-6.4 cm (1-2g)	96h-TLm	7.5	25	7.8	18	20	48.5	S/U	SA	Pickering & Henderson, 1966
		96h-TLm	7.5	25	7.8	18	20	40	S/U	SA	Pickering & Henderson, 1966
		96h-TLm	8.2	25	7.8	300	360	42.3	S/U	SA	Pickering & Henderson, 1966
		96h-TLm	8.2	25	7.8	300	360	36	S/U	SA	Pickering & Henderson, 1966
		48h-TLm	7.5	25	7.8	18	20	48.5	S/U	SA	Pickering & Henderson, 1966
		24h-TLm	7.5	25	7.8	18	20	48.5	S/U	SA	Pickering & Henderson, 1966
		48h-TLm	8.2	25	7.8	300	360	42.3	S/U	SA	Pickering & Henderson, 1966
		24h-TLm	8.2	25	7.8	300	360	42.3	S/U	SA	Pickering & Henderson, 1966
	28-32 days old (ave. 0.088g)	96h-LC50	7.2	22.3±0.35	7.1±0.52	41.5±0.58	50.0	9.1	F/M	SA	Geiger et al., 1990

KEY (1)
TLm = Median Tolerance Limit
LC = Lethal Concentration
IC = Immobilization Concentration
EC = Effects Concentration

KEY (2)
S = Static
F = Flowthrough
U = Unmeasured Toxicant Concentration
M = Measured Toxicant Concentration
R = Renewed Static

KEY (3)
P = primary
S = secondary
T = tertiary
A = acute toxicity
C = chronic toxicity

TABLE 2: AQUATIC TOXICITY DATA FOR ETHYLBENZENE

SPECIES	LIFE STAGE	RESPONSE KEY (1)	TEST CONDITIONS pH	TEMP. (°C)	D.O. (mg/L)	ALK. (mg/L)	HARD (mg/L)	EFFECT CONC. (mg/L)	DATA CODES KEY (2)	DATA QUALITY KEY (3)	REFERENCES
Goldfish *(Carassius auratus)*	3.8-6.4 cm (1-2g)	96h-TLm	7.5	25	7.8	18	20	94.4	S/U	SA	Pickering & Henderson, 1966
		96h-TLm	7.5	25	7.8	18	20	73	S/U	SA	Pickering & Henderson, 1966
		48h-TLm	7.5	25	7.8	18	20	94.4	S/U	SA	Pickering & Henderson, 1966
		24h-TLm	7.5	25	7.8	18	20	94.4	S/U	SA	Pickering & Henderson, 1966
Bluegill sunfish *(Lepomis macrochirus)*	0.32-1.2g	24h-LC50	6.7-7.8	22±1	7.0-8.8	28-34	32-48	169	S/U	SA	Buccafusco et al., 1981
		96h-LC50	6.7-7.8	22±1	7.0-8.8	28-34	32-48	150	S/U	SA	Buccafusco et al., 1981
	0.2g	96h-LC50	7.2-7.5	17±1		30-35	40-50	88	S/U	SA	Johnson & Finley, 1980
	3.8-6.4 cm (1-2g)	96h-TLm	7.5	25	7.8	18	20	32	S/U	SA	Pickering & Henderson, 1966
		96h-TLm	7.5	25	7.8	18	20	29	S/U	SA	Pickering & Henderson, 1966
		48h-TLm	7.5	25	7.8	18	20	32	S/U	SA	Pickering & Henderson, 1966
		24h-TLm	7.5	25	7.8	18	20	35.1	S/U	SA	Pickering & Henderson, 1966

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TABLE 2: AQUATIC TOXICITY DATA FOR ETHYLBENZENE

SPECIES	LIFE STAGE	RESPONSE KEY (1)	TEST CONDITIONS					EFFECT CONC. (mg/L)	DATA CODES KEY (2)	DATA QUALITY KEY (3)	REFERENCES
			pH	TEMP. (°C)	D.O. (mg/L)	ALK. (mg/L)	HARD (mg/L)				
Guppy *(Lebistes reticulatus)*	1.9–2.5cm (0.1–0.2g 6 months)	96h–TLm	7.5	25	7.8	18	20	97.1	S/U	SA	Pickering & Henderson, 1966
		96h–TLm	7.5	25	7.8	18	20	78	S/U	SA	Pickering & Henderson, 1966
		48h–TLm	7.5	25	7.8	18	20	97.1	S/U	SA	Pickering & Henderson, 1966
		24h–TLm	7.5	25	7.8	18	20	97.1	S/U	SA	Pickering & Henderson, 1966
(Poecilia reticulatus)		96h–LC50		21±1				9.6	R/M	PA	Galassi et al., 1988
Channel catfish *(Ictalurus punctatus)*	0.1g	96h–LC50	7.2–7.5	22±1		30–35	40–50	210	S/U	SA	Johnson & Finley, 1980
Rainbow trout *(Oncorhynchus mykiss)*	2.4g	96h–LC50	7.2–7.5	12±1		30–35	40–50	14	S/U	SA	Johnson & Finley, 1980
		96h–LC50		12±1				4.2	R/M	PA	Galassi et al., 1988
Golden orfe *(Leuciscus idus)*		48h–LC50						44	S/U	SA	Juhnke and Lüdemann, 1978

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TABLE 2: AQUATIC TOXICITY DATA FOR ETHYLBENZENE

SPECIES	LIFE STAGE	RESPONSE KEY (1)	TEST CONDITIONS pH	TEMP. (°C)	D.O. (mg/L)	ALK. (mg/L)	HARD (mg/L)	EFFECT CONC. (mg/L)	DATA CODES KEY (2)	DATA QUALITY KEY (3)	REFERENCES
INVERTEBRATES											
Cladoceran *(Daphnia magna)*	<24 hrs old	48h-LC50	7.0±0.2	22±1	8.8		72±6	75	S/U	SA	LeBlanc, 1980
		24h-LC50	7.0±0.2	22±1	8.8		72±6	77	S/U	SA	LeBlanc, 1980
		no effect	7.0±0.2	22±1	8.8		72±6	6.8	S/U	SA	LeBlanc, 1980
		24h-EC50 (immob.)						2.2	S/M	PA	Galassi et al., 1988
		48h-EC50 (immob.)	6-7	23±2	5-9			2.1	S/U	SA	Bobra et al., 1983
OTHER ORGANISMS											
Selenastrum capricornutum		72h-EC50 (growth inhibition)						4.6	S/M	SC	Galassi et al., 1988

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TABLE 2: AQUATIC TOXICITY DATA FOR ETHYLBENZENE

SPECIES	LIFE STAGE	RESPONSE KEY (1)	TEST CONDITIONS					EFFECT CONC. (mg/L)	DATA CODES KEY (2)	DATA QUALITY KEY (3)	REFERENCES
			pH	TEMP. (°C)	D.O. (mg/L)	ALK. (mg/L)	HARD (mg/L)				
Selenastrum capricornutum		8d-EC50 (growth inhibition)						4.8	S/M	SC	Herman et al., 1990
Scenedesmus quadricauda		cell mult. inhib. test toxicity threshold						>160		TC	Bringmann & Kuhn, 1980
Bacterium Pseudomonas putida		cell mult. inhib. test toxicity threshold						12		TC	Bringmenn & Kuhn, 1980
Protozoan Entosiphon sulcatum		cell mult. inhib. test toxicity threshold						140		TC	Bringmann & Kuhn, 1980
Dicranophorus forcipatua		6d-EC54 (growth inhib.)						173	S/U	SC	Erben, 1978

KEY (1)
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EC = Effects Concentration

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M = Measured Toxicant Concentration
R = Renewed Static

KEY (3)
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T = tertiary
A = acute toxicity
C = chronic toxicity

Table 3: UNCERTAINTY FACTOR WORKSHEET

CHEMICAL:	CAS No.	CONCENTRATION UNITS
Ethylbenzene	100-41-4	mg/L

Test Conditions		Species (life stage)	Toxicity End Point	Effect conc.	[1] Data Codes	[2] Data Type	Calibration Factor	Reference
ACUTE	VERTEBRATE	Fathead minnow	96h-LC50	9.1	F/M	2°	0.9	Geiger *et al.* 1990
		Guppy	96h-LC50	9.6	R/M	1°	0.8	Galassi *et al.* 1988
		Rainbow trout	96h-LC50	4.2	R/M	1°	0.8	Galassi *et al.* 1988
	INVERT.	*Daphnia magna*	24h-EC50	2.2	S/M	1°	0.8	Galassi *et al.* 1988
CHRONIC	VERTEBRATE							
	INVERT.	*Dicranophorus forcipatus*	6d-EC50	173	S/U	2°	0.7	Erben, R. 1978
	PLANT	*Selenastrum capricornutum*	72h-EC50	4.6	S/M	2°	0.9	Galassi *et al.* 1988

CALCULATION OF FINAL UNCERTAINTY FACTOR:

Since Log Kow < 4.00, The Baseline Uncertainty Factor = 1000

Baseline Uncertainty Factor X Calibration Factors (maximum number = 11)

1000 X [0.9] X [0.8] X [0.8] X [0.8] X [0.7] X [0.9] X [ ] X [ ] X [ ] X [ ] X [ ]

= 290 FINAL UNCERTAINTY FACTOR

CRITICAL VALUE ÷ FINAL UNCERTAINTY FACTOR = PWQG

= 2.2 ÷ 290 = 0.008 mg/L

[1] Assign 2 DATA CODES, one from each of the following rows:
S = static R = static/renewal F = flowthrough
U = unmeasured nominal conc. M = measured conc

[2] DATA TYPE:
1° = Primary 2° = Secondary 3° = Simulated Data
? = Unknown (Default Data Quality = 2°)

FIG. 1: TOXICITY SUMMARY AND GUIDELINE DERIVATION GRAPH